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Buchans Ecological Engineering Treatment Assessment

Long-term performance evaluation and Site Visit Report (2009)

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Objective of the data assembly

The decommissioning effort of the Buchans Waste Management area was carried out by Boojum Research Ltd for ASARCO between 1988 and 1998. A biological polishing pond system was installed treating combined effluents from Orientals, Valley Seeps and Drainage Tunnel. Work in the Hospital tailings spill area addressed the distribution of the metals to a depth of 0.5m and defined the contaminant loading to the Turnpike and the Buchans River.

Based on these data a fresh water diversion ditch was constructed and test plots were set up to generate a hardpan below ground, where iron and metals precipitated with phosphate sand and a cover was provided for vegetation to prevent erosion. The test results were very positive and the PHITO (**P**hosphate **H**eterotroph **I**nhibition of **T**ailings-**O**xidation) was implemented prior to the death of G. Neary.

Boojum Research Ltd is a research company, developing sustainable decommissioning technology based on Ecological Engineering principles.

An assessment of:

a) the effectiveness of the fresh water diversion ditch in the Hospital tailings spill;

b) the PHITO system for erosion control in the same area ;

c) the biological polishing system;

has been carried out in October 2009 by Boojum Research Ltd. The data are provided to the Newfoundland regulatory agencies to assist in selecting the best possible scale up options for the complete remediation of the waste management area.

The complex hydrology and geochemistry of the Buchans waste management area, documented to a large extent in the work carried out for ASARCO in the past, precludes to a large extent successful application of conventional treatment approaches.

Section 1: Mucky ditch - Hospital tailings 1994 to 2009 assessment

The sampling grid of the pits dug in 1994 in the area of the Hospital tailings also referred to as the Mucky Ditch indicate the sampling locations (Figure 1, source AB046 page 19). The locations where measurements were carried out in 2009 are indicated in colored boxes, **lilac** for the PHITO ditch, **red** for the background *i.e.* uncontaminated, **blue** the old tailings drainage, now receiving overflow from the new barite tailings ponds and **green** the location of the junction of the fresh water diversion ditch with the PHITO ditch. Water samples are with Dr. S. Alam, Department of Civil Engineering at Memorial University.

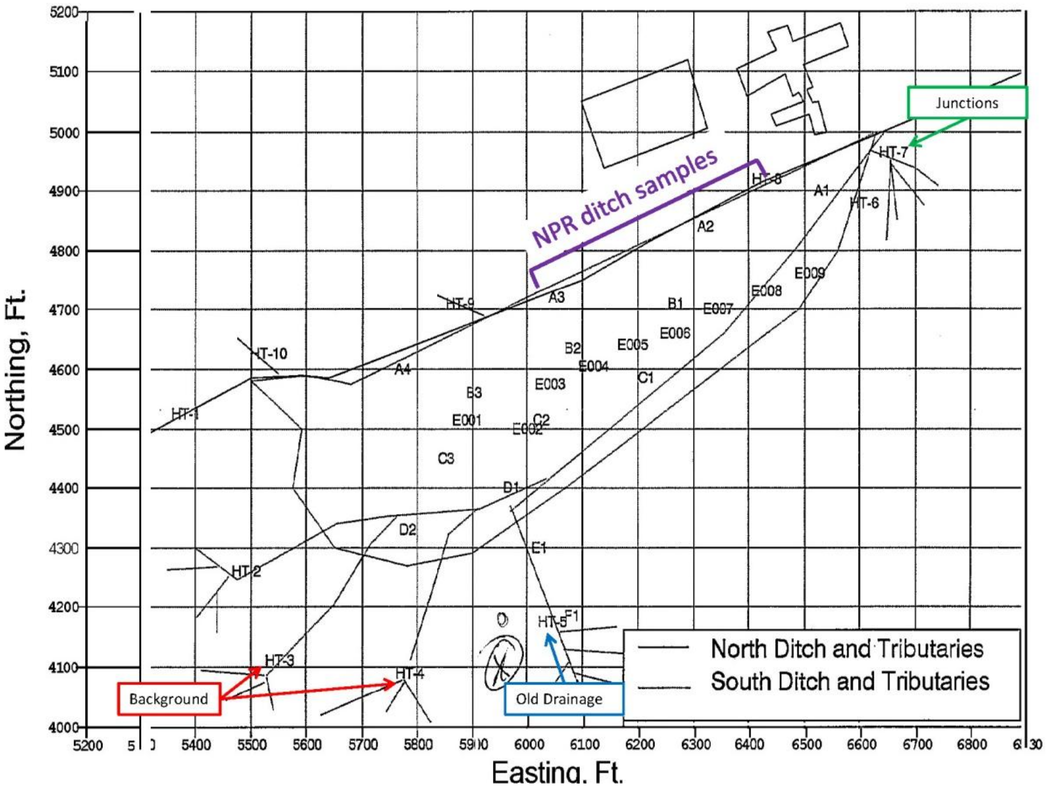


Figure 1. Buchans Hospital tailings Sampling Locations

Two sets of pH values from the past are presented. The first set of data is presented in Figure 2. The type of solid material is described and the values of pH and electrical conductivity of slurries (10 g of sample and 50 ml of distilled water) made from the solid samples collected to a depth of approximately 0.5 m.

The pH values are acid but note, station E1 the lowest pH was measured in the black peat material pH 2.7. The highest value is reported in un-oxidized buried (>40cm) un-oxidized tailings. Mr. Neary had imported till to cover the spill areas of concentrate tailings some time prior to our investigation. This measure clearly had prevented further oxidation up 1994.

The electrical conductivities have a large range from as low as 80 to 2090 μS/cm, indicating the localized distribution of the metal contamination. Elemental analysis of the solid samples, depicted for iron, zinc, copper and lead in submitted in report to the regulatory agencies by Asarco in 1994 or 1995 (Report AB046.pdf).

The second set historical data provided are surface water samples collected in 1994, unfortunately after an intensive rain (Table 1). Hence the electrical conductivities are somewhat diluted when compared to 2009, where approximate locations are indicated (Table 2).

The water characteristics with respect to electrical conductivity are similar to the values reported from the slurries made from the excavated pits (Figure 1; see Table 1 , AB046, pf 13). This would be expected given the intensive rain period prior to the 1994 sampling and the resulting flow see Table 4b of AB046 pg 16 copied below.

Table 1: Hospital Tailings Area soil strata description (July 14,1994) and slurry pH, Cond (10g+50mL DH2O).

Station	Stratum	Sam	Description	pH	Cond
Stn A1	0-5 cm		New organic soil with roots, good vegetation cover		
	5-15 cm	A	Imported pink till (sand and gravel)	4.7	95
	15-24 cm	B	Light yellow oxidized tailings	3.1	1864
	> 4 cr	C	Dense black saturated original peat	3.57	604
Stn A2	0- cm		New organic soil with roots, g(od v([illegible]		
	8-28 cm	A	Imported pink till	4.05	344
	28-41 cm	B	Yellow, red oxidized tailings	3.45	2040
	<41 cm	C	Gray unoxidized tailings	4.22	1752
Stn A3	0-12 cm		Yellow oxidized tailings; till eroded away, no vegetation cover		
	12-16 cm	A	Red oxidized strata in unoxidized gray tailings	3.18	2090
	16->46 cm	B	Dark gray unoxidized tailings; strong odour of flotation agents	4.61	1805
Stn A4	0-10 cm	A	Imported pink till	3.9	392
	10-16 cm		Slightly oxidized tailings		
	16-31 cm	B	Red oxidized strata in unoxidized gray tailings	4.76	1829
	<31 cm	C	Dense black saturated original peat	4.04	102
Stn B1	0-10 cm		Peat and roots; Complete vegetation cover; pooling in area		
	10-28 cm	A	Imported pink till	4.38	80
	28-40 cm	B	Red, yellow oxidized strata in unoxidized gray tailings	4.52	101
	> 40 cm	C	Unoxidized light gray tailings	5.34	1833
Stn B2	0-9 cm		Peat and pink till, partially vegetated		
	9-24 cm		Dark peat		
	24-43 cm	A	imported pink till	4.35	288
	43-50 cm	B	Red, yellow oxidized strata in unoxidized gray tailings	3.84	1920
	> 50 cr	C	Medium gray unoxidized tailings	4.8	1703
Stn 83	4 cm		Imported pink till, some peat, no egetati n		
	4-20 cm	A	Tailings and peat strata	4.31	830
	20->43 cm	B	Original black peat	3.28	1037
Stn C1	0-23 cm		imported pink till		
	23-50 cm		Oxidized red, yellow tailings		
	[illegible] cm		Hard gray unoxidized tailings		
Stn C2	0-8 cm		Imported pink till, sparsely vegetaated with grass, moss		
	8-46 cm		Oxidized red, yellow oxidized tailings strata in gray unoxidized tailings		
	>46 cm		Gray, unoxidized tailings		
Stn C3	0-8 cm		imported pink till, 50% vegetated with grass, moss		
	8-35 cm		Coarse oxidized tailings		
	> 35 cm		Soft unoxidized tailings		
Stn D1	0-7cm		imported pink till		
	7-42 cm		Yeiiow, red oxidized tailings		
	42->58 cm		Unoxidized coarse gray tailings		
Stn D2	0-2 cm		Moss		
	2-41 cm		Slightly oxidized gray tailings		
	41->44 cm		Gray coarse unoxidized tailings		
Stn E1	0-25 cm	A	Red oxidized tailings, possibly eroded to location	3.12	1348
	25->36 cm	B	Original black peat	2.77	1975
Stn F1	0-25 cm	A	Original black peat, absolutely no vegetation	3.57	200
	> 25 cm	B	Till	4.53	100

Figure 2. Table 1 from AB064 Report.

Table 1. Water samples collected in Hospital Tailings area during July 10-15, 1994 Buchans site visit.

Sampling	Easting	Northing	pH	Cond	Eh	T	Acidity	Flow
	ft		unit	µS/cm	mV	ºC		L/min
HT-1	5380	4525	5.15	590	468.8	19.3	38.4	16
HT-2	5490	4260	3.25	900	507.9	19.1	378.2	2.3
HT-3	5550	4110	3.56	432	535.9	19.1	37.3	38.2
HT-4	5785	4090	4.88	308	430.8	19.2	21.9	102
HT-5	6045	4175	4.23	30	496.8	19.3	17.9	1.5
HT-6	6605	4880	4.25	370	485.7	19.4	45.5	168
HT-7	6660	4965	3.62	435	546.8	19.2	94.9	11.2
HT-8	6430	4920	3.36	690	560.4	19.9	309.9	82.5
HT-9	5875	4710	4.42	310	520.9	19.1	83..3	39
HT-10	5530	4625	5.16	272	487.0	19	68.2	3.3
Williams Turnpike	6870	4850	4.72	500	451.1	20.3	102.8	360

Table 2. Phito ditch / NPR lined and fresh water diversion ditch assessment (2009)

Description	pH	Cond	Eh	Temp.
	unit	µS/cm	mV	ºC
Tailings Pond	6.31	697	232.7	9.04
Tailings Pond - Across road	6.35	942	236.8	7.78
Taillings Pond - Second)	6.39	536	190	9.01
Upstream Pond	4.94	2336	271.3	8.12
Upstream Pond equivalent to location HT-5	6.28	2333	189.7	8.28
Background	3.18	1488	480.1	8.67
Pipe Samples HT 3 and 4	3.62	1486	354.8	9.36
Diversion Ditch	2.63	2458	503	9.2
Diversion Ditch	3.19	1192	467.6	8.6
Diversion Ditch	4.42	2672	277	8.82
Diversion before junction with NPR ditch HT-6	4.06	1070	354.3	9.95
NPR / PHITO ditch half way HT-9	3.3	2640	436.8	10.25
NPR Ditch	3.2	2450	440.9	10.19
NPR Ditch HT- 8	2.98	3220	466.7	10.31

The pH value distribution of the surface and the bottom samples in the investigated area in 1994 (Figure 3) were used to determine the location of the fresh water diversion ditch, as higher pH values were recorded on the grid around 4400 Northing and 6200 Easting.

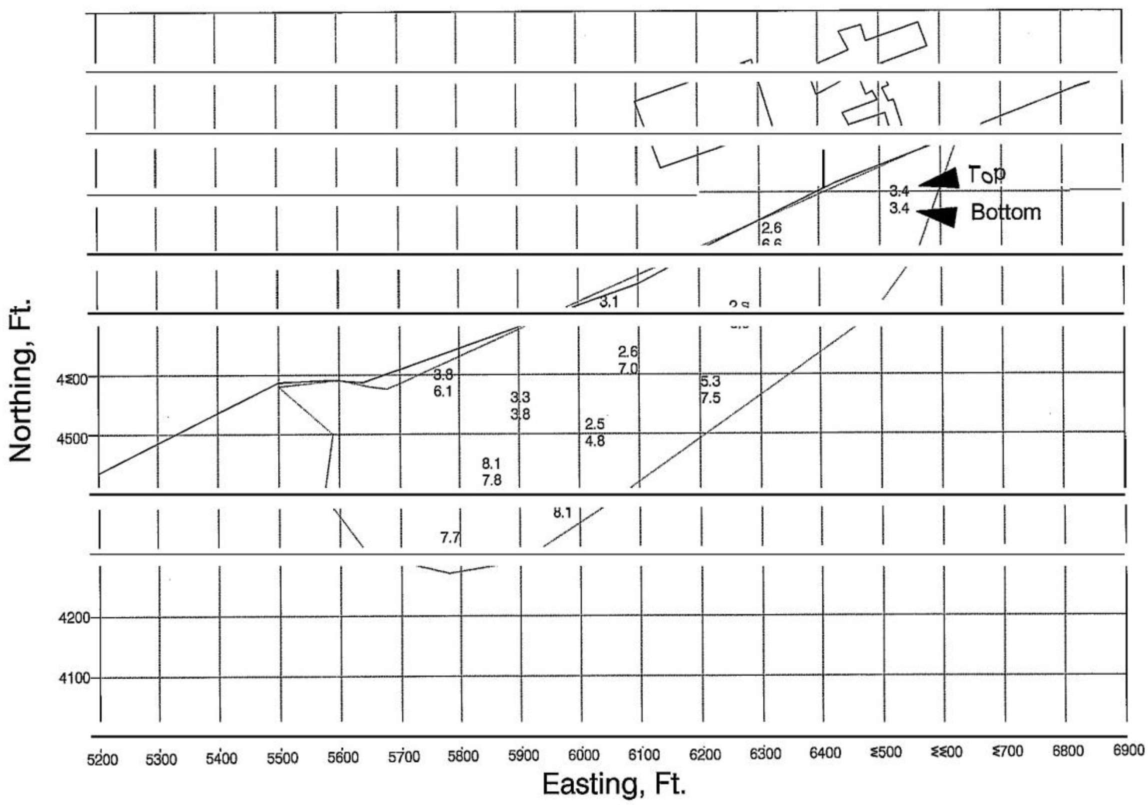


Figure 3. Buchans Hospital Area Tailings slurry pH values surface and bottom (1994)

In Figure 4 the flows measured at the Williams Turnpike (Fall 1993 to Jan 1994) indicate large variations of flows from the drainage basin exhibit large variations.

Table 4b: Zinc, copper and lead daily loadings at Williams Turnpike, ASARCO DATA.

	03-Aug-93	18-Sep-93	10-Oct-93	23-Oci-93	09-Nov-93	21-Nov-93	28-Nov-93	13-Dec-93	1l-Jan-94	30-Jan-94
pH	3.8	3.3	3.6	3.6	4	3.9	5.7	4.2	4.4	4.2
Flow. L/min	2839	189	2839	1136	757	379	379	7571	568	757
Zn load,kg/day	157.2	31.1	263.9	90.8	57.2	21.0	0.2	140.1	14.6	11.0
Cu Load, kg/day	NA	0.6	NA	NA	NA	0.9	NA	NA	NA	NA
Pb Load, kg/day	NA	NA	NA	NA	NA	0.9	NA	NA	NA	NA

NA No1 Available

Figure 4 . Table 4b from AB064 Report.

The three measurements of the surface water in the PHITO lined cannot be assessed, since we unfortunately did not sample the water at location HT-1 and HT-10 in 2009 (see Figure 1). At that time, near neutral water was entering reflecting the background water quality. Given the activities around the mill, this may no longer be the case.

The chemical analysis of water and solid samples collected from the ditch lining would have to be obtained in addition to solid samples from the lining. <u>However the application certainly has halted any erosion from the ditch.</u> The banks are well covered with vegetation the lined ditch (see Plate 12 appendix)and the unlined fresh water diversion ditch for comparison (see Plate 8 appendix).

Section 2 : The OEP pit

The zinc removal process is based on iron oxidation which leads in the formation of an iron hydroxide precipitate which in turn, adsorbs or co-precipitates Zn. The algae in the biological polishing ponds collect the particles. The zinc and iron precipitates with the algal biomass sink to the bottom sediment. The brush in the pond provides surface area for attached algae to grow and supply the nutrients needed for the algae.

Given the ice formation on the OEP in the winter, no oxidation takes place and therefore no zinc removal can take place. It would be possible to keep the ice of the pits, but owners rejected the expense and the regulatory bodies accepted the winter conditions at the time.

1 . The status of the OEP pit water chemistry

Given the driver of the zinc removal process is the oxidation of iron, it is essential that the Eh values are between 300-400 mV. The last measurements of these parameters were made in 1996 and they are given with the values measured during the site visit in Table 3. The pH values on the surface are about 1 unit lower in 2009 and the Eh values are reflecting lower Eh conditions.

Table 3. Comparison between OEP profile measurements in 1996 and in 2009

	Depth	Temp.	pH	Cond	Eh
	m	ºC	unit	µS/cm	mV
1996	0	16.4	7.52	1331	293
	0	16.4	7.24	1357	415
	2	18.5	6.9	2000	
	6	7.8	6.59	2600	128
	18	10.8	6.3	1925	
	20	8.5	6.47	3010	107
2009	1	9.3	6.5	2178	88
	3	8.3	6.53	2343	54
	5	8.2	6.27	2346	45.5
	14	8.4	6.13	2800	30.3
	14	8.3	6.1	2860	24.6

As Eh readings are seasonal, all available profiles measurements from the past are plotted in Figure 5 and 6, such that the potentially acidifying trend (drop in 1 pH unit) can be supported by a larger data set. The electrical conductivity has remained the same and also the temperature is within the same range as previously measured. Dissolved oxygen was unfortunately not recorded in 2009 but would be expected to be lower, given the Eh, which has clearly decreased.

Using the monitoring data of the OEP final effluents (Figure 7) the zinc concentration of the OEP has remained between 10 and 20 mg/l. The flows seem to be within the same range over the years and pH is also within the same range for the effluent. Thus the vertical noted acidification is unlikely of importance. <u>However the reduction in Eh is of concern as it will hinder zinc removal. A more complete investigation of the pit limnological profiles is required along with the OWP pit .</u>

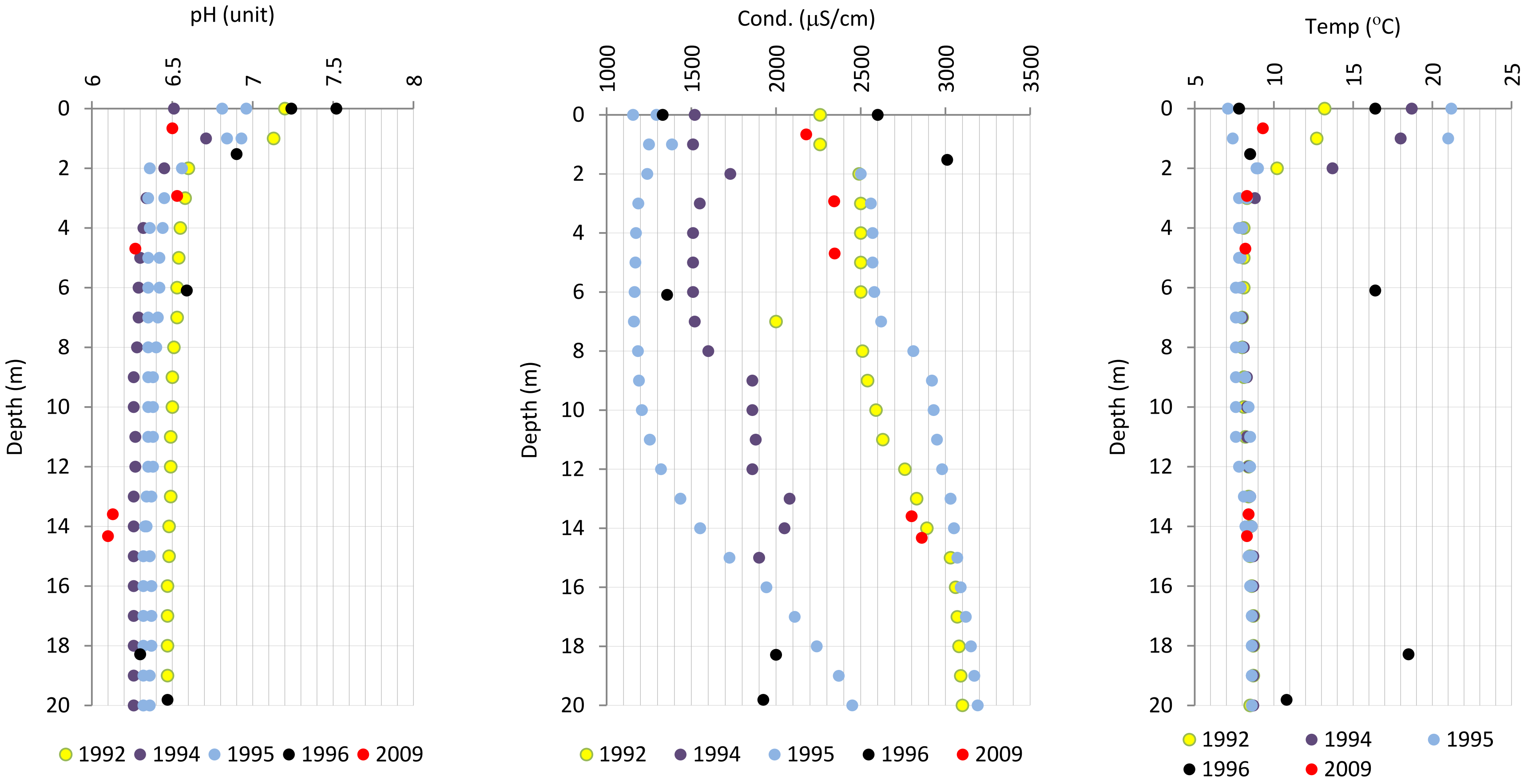


Figure 5. OEP pH, Conductivity and Temperature profile measurements between 1992 and in 2009

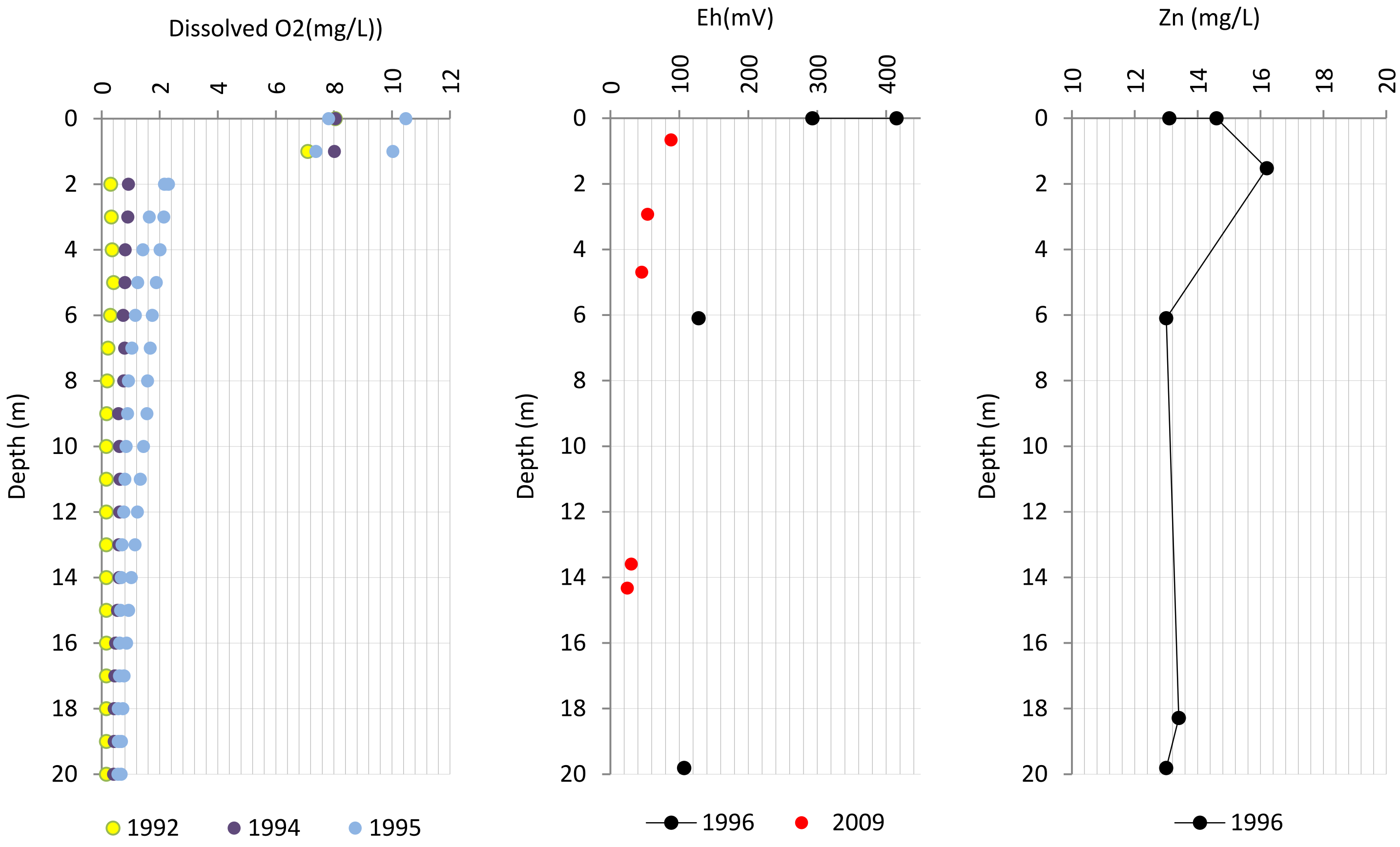
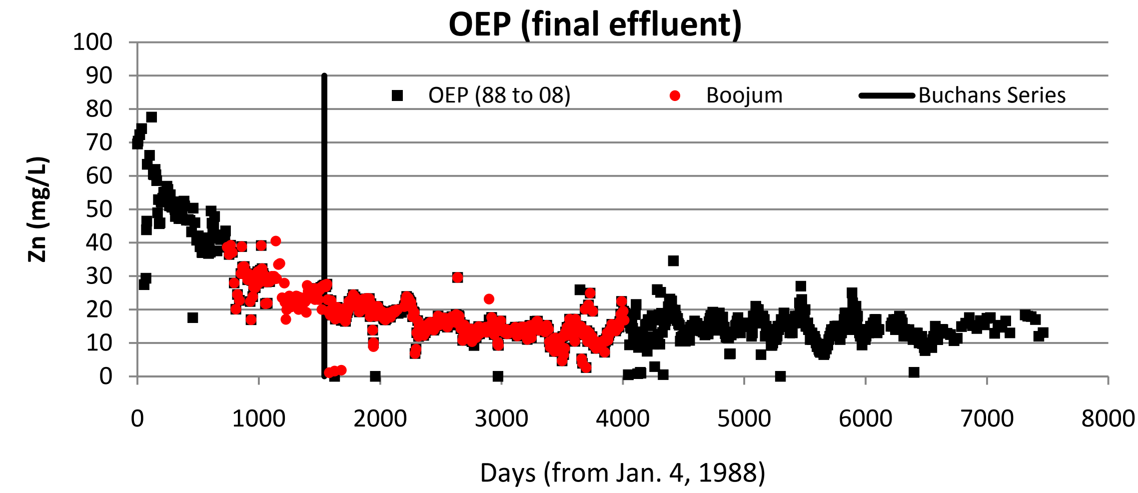
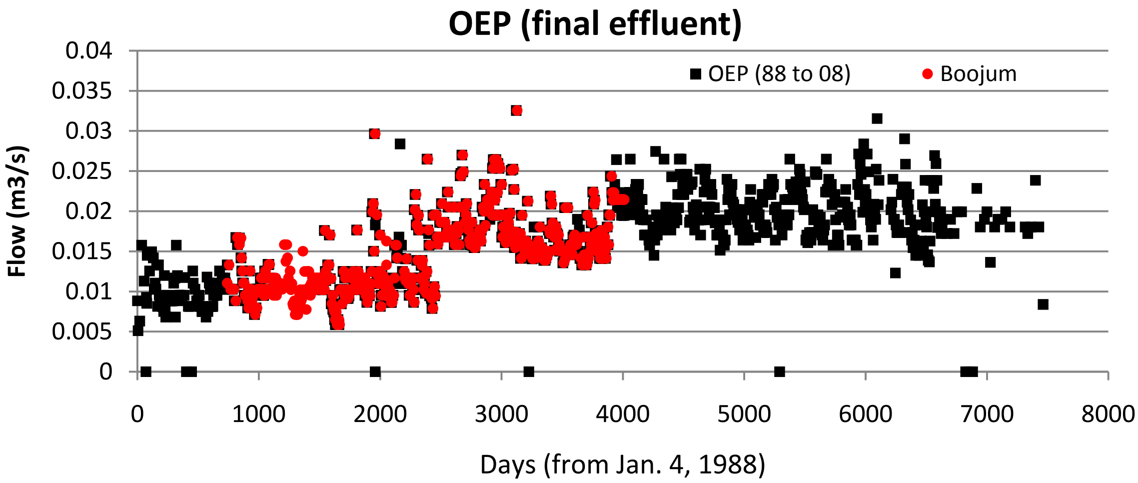


Figure 6. OEP Dissolved oxygen profile measurements between 1992 and 1995, Eh comparison between 1996 and 2009 measurements; OEP Zn concentration in 1996





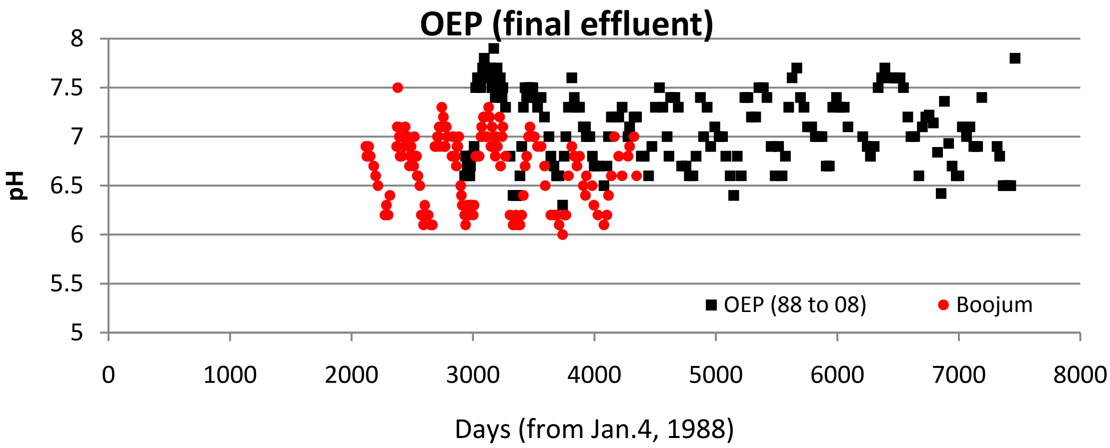


Figure 7. OEP Performance (1988-2008)

Section 3: The Polishing Ponds

The layout of the polishing ponds is given in Figure 8. The same numbering system has been used to assess the polishing ponds. The two systems work in parallel as the effluent from the OEP are split and should enter the same amount of water to both sides. This is no longer the case , as pool 10 receives considerably less water than pool 14.

In system 2, (14 inflow to 17 outflow) the inflow has the highest redox reported of the entire system, both at the weir edge and at the bottom. All other pools have a low redox or Eh value.

From visual observations the algal populations are not as extensive as they were previously, which also reduces the oxygen production by the algae, reducing the zinc removal. As the ponds were cleared out, much of the brush has been removed, which was unavoidable, but hinders removal of the contaminants. It is not clear what motivated the clearing of the pools.

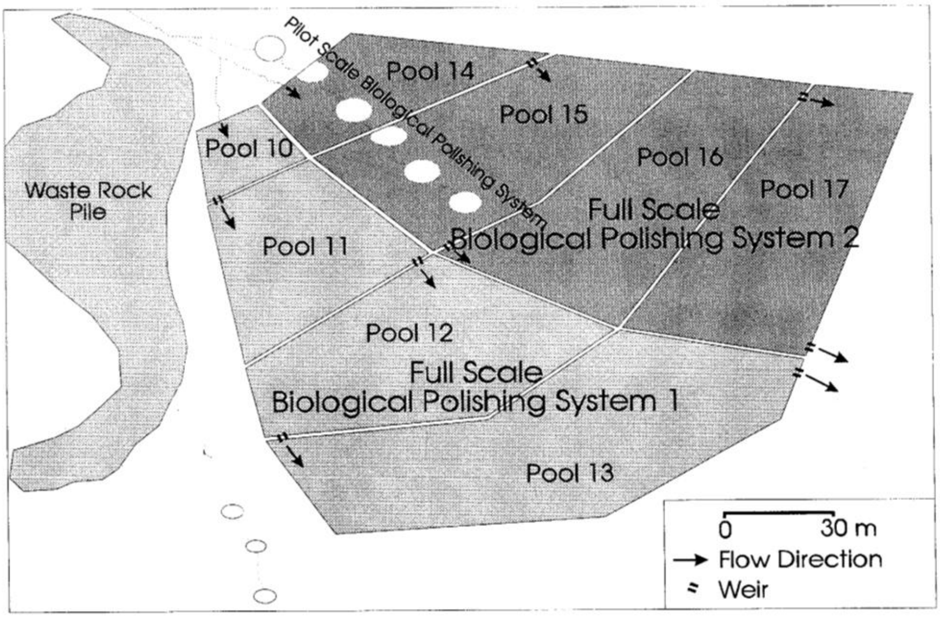


Figure 8. Layout of Biological Polishing Ponds 10 through 13 (Biological system 1) and 14 to 17 (Biological system 2).

In Table 4 the measurements made at the weirs between the pools are given.

Table 4**.** 2009 Polishing ponds

Description	pH unit	Cond µS/cm	Eh mV	Temp. ºC
Pool 14	5.69	2143	172.1	11.18
Pool 14 deep measurement	6.4.	2116	206.6	10.73
Seepage Pool 17	6.88	1483	-44.7	15.19
Pool 17 deep measurement	6.87	2049	3.3	11.24
OEP effluent Inflow Pool 10	6.94	2178	68.7	10.59
OEP effluent input to Pool 14	6.93	2151	57	10.6
Pool 11	7.06	2114	81.9	10.79
Pool 12	7.22	2087	95	10.93

In Figure 9, the performance of the final effluents of the polishing system is given. The initial seasonal fluctuations are very pronounced up to day 5700 or August 2003. It is evident that the summer low concentrations are decreasing from that time on. This is likely a reflection of the reduced oxidation capacity of the system. Apparently sugar was added at the pumping station at one point in time. This addition had likely little effect in the pond performance as sugar is water soluble and would have left the system within days. The flows to the system have remained the same since Boojum worked there (see Fig 9). The initial large variations in the flows were due to the gradual additions of additional effluent streams up the 1999.

Further additions were reported to have been made to the OWP and the OEP in the form of biosolids. This was likely quite destructive to removal as these solids promote microbial iron reduction. This will take place initially rather rapid , due to the easily degradable carbon utilized by iron reducing microbes followed by a slower phase as the recalcitrant or hard to degrade carbon will have its effect in the long term.

From our perspective, the system can be easily brought back to its original performance and we would welcome to cooperate with any interested party. Most economically, the work could be achieved with a local contractor after a full investigation of the entire flow system.

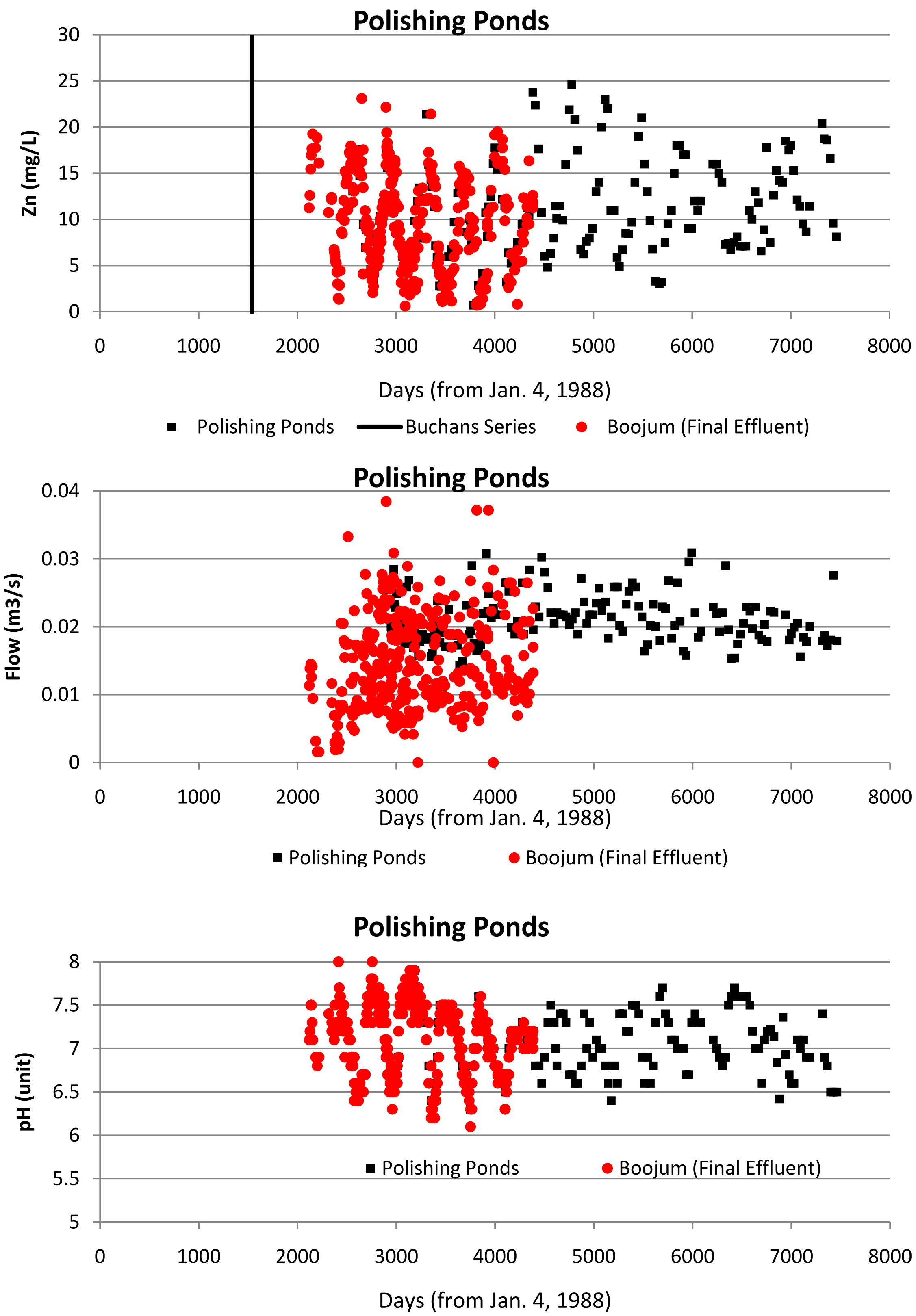
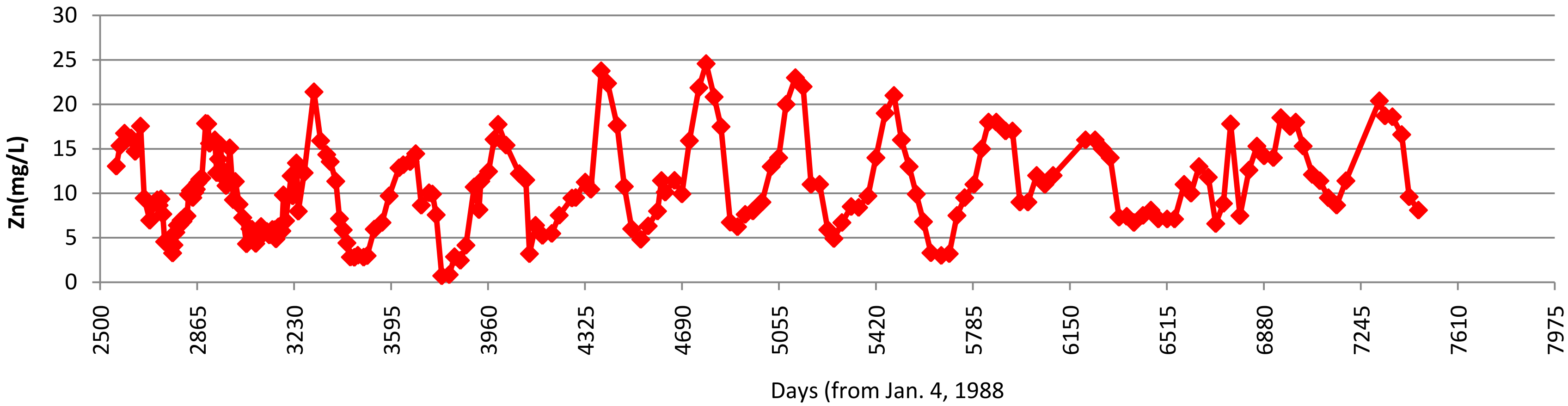


Figure 9. Polishing Ponds performance (1993-2008) (Final Boojum effluent corresponds to Pool 13 and 17)



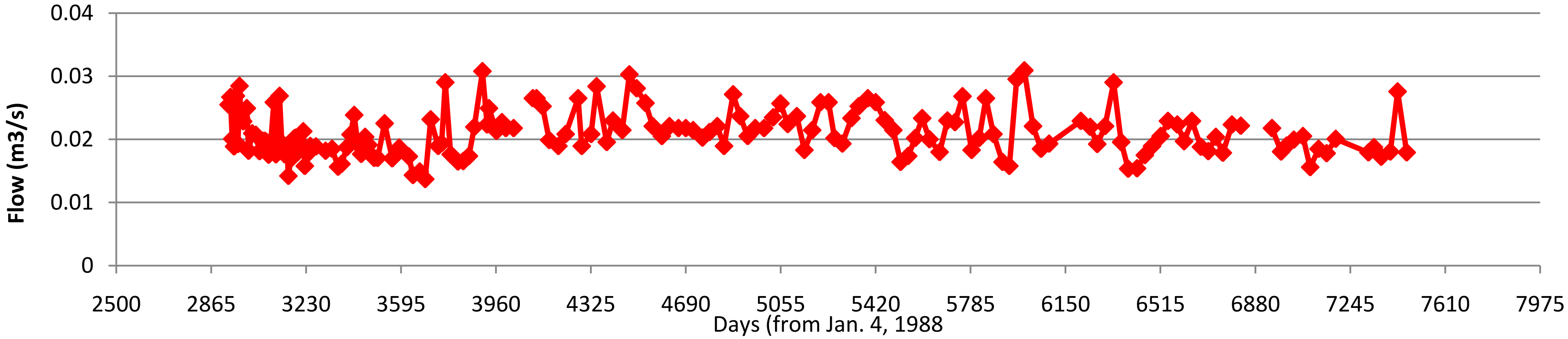


Figure 10. Long-term performance of Polishing pond

APPENDIX 1

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Plate 4. 12) NPR/PHITO ditch half way; 13) and 14) NPR ditch. 5

Plate 5. 15) Pool 17 deep measurement; 16) Pool 14; 17) Pool 14 deep measurement; 18) Pool 17- Seepage. 6

Plate 6. 19) Poll 10 Inflow; 20) OEP effluent input to Pool 10; 21) Pool 11; 22) Pool 12. 7

Plate 1. 1) Tailings pond; 2) Tailings Pond - Across road; 3) Tailings Pond (Second)

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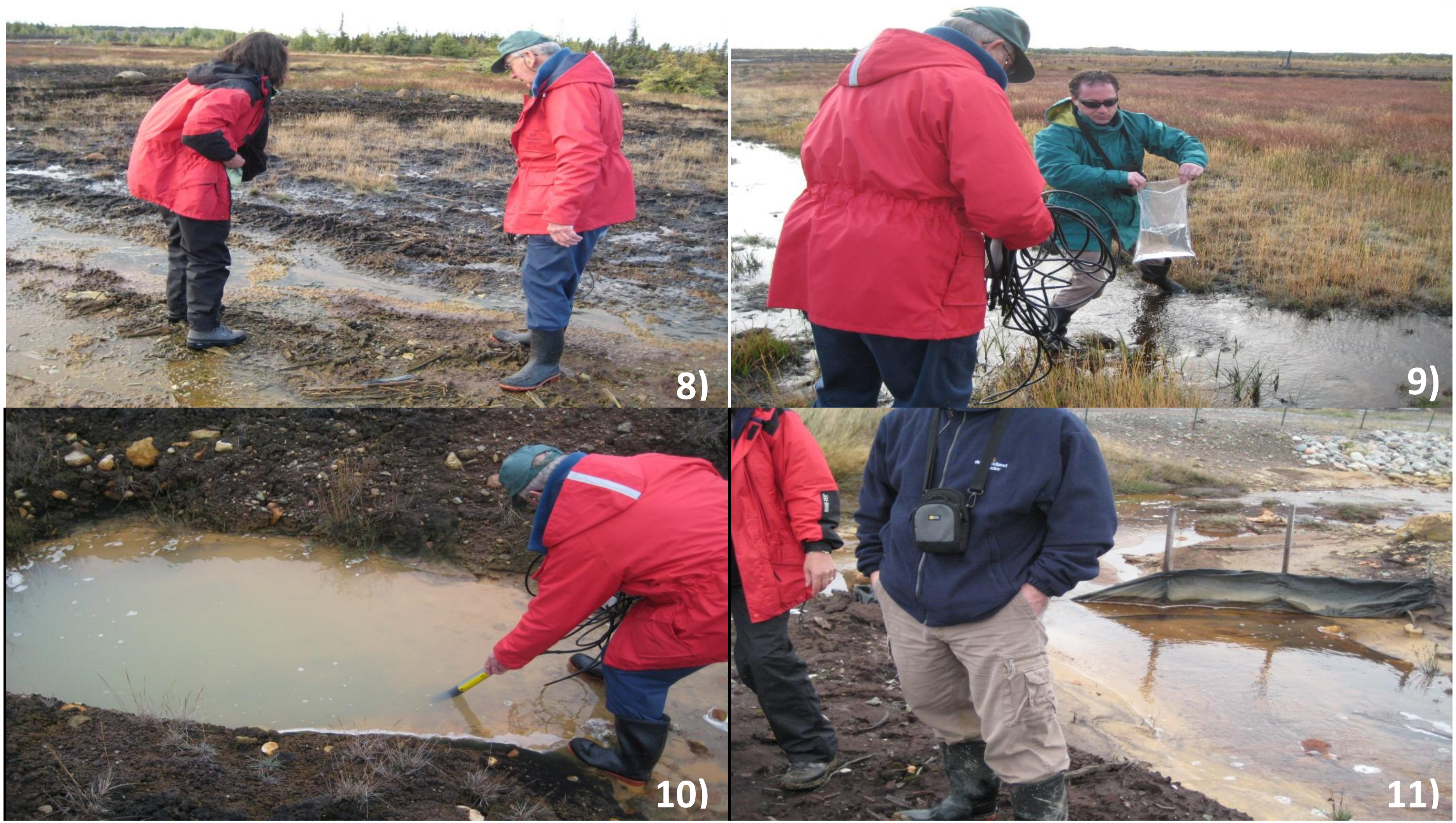

Plate 3. 8), 9) and 10) diversion ditch; 11) Diversion ditch before junction with NPR ditch.

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